Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.6, 2015

Assessment of Natural Radioactivity and Radon indoors in the New Campus of the Princess Nora University and the Associated Health Hazards

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Abstract

Surveillance monitoring in the new campus of Princess Nora University has been carried out to ensure that the radiation doses received to the public are below the authorized limits, as well as providing a base-line data on background radiation inside the campus. Soil and tap water samples were collected from selected locations in the campus, and indoor radon was measured in three selected buildings through its daughter Po-218, with a silicon alpha detector (RAD-7). Tap water samples were analyzed for radium isotopes (Ra-226 & Ra-228) and measured by gamma spectrometry using high purity germanium detector, after radiochemical separation of the isotopes with ion-exchange chromatography using a strong cation resin. The activity concentrations of 226Ra, 228Ra (232Th series), 137Cs and 40K were determined in the soil samples. Quality assurance and methods validation were established through the efficiency calibration of the detectors, the estimation of uncertainties, the use of blanks, the analysis of standard reference materials and the intercomparison and proficiency tests. The average activity concentrations of 226Ra, 228Ra (232Th series), 137Cs and 40K in soil were 9.3, 9.0, 0.2 and 122.5 Bq/kg respectively, and the corresponding radium equivalent activity had an average of 31.7 Bq/kg, which is far below the value of 370 Bq/kg, as reported in the UNSCEAR. The average absorbed dose rate from outdoor gamma radiation one meter above the ground was 15.4 nGy/hr, which is far below the world average value of 57.0 nGy/hr and the reported values from different regions in KSA. The indoor radon concentrations had an average of 11.8 Bq/m3, which is much lower than the recommended ICRP action level of 200 Bq/m3. The average activity concentrations of 226Ra and 228Ra were 5.3 and 11.0 pCi/L respectively, which is considered in violation of the Saudi Arabian Standards Organization (SASO) authorized limit of 2.7 pCi/L for 228Ra, and the average combined contribution of 226Ra and 228Ra activities to the effective dose from a year's consumption of drinking water in the campus was 0.24 mSv/y, which exceeded the 0.1 mSv/y limit allowed by WHO in drinking water.

Keywords: natural radioactivity monitoring, radium, drinking water, radon, Saudi Arabia.

1. INTRODUCTION

Naturally occurring radionuclides are widespread in the earth's environment and they exist in various matrices such as soil, rock, water and plants. These radionuclides pose exposure risks externally due to their gamma ray emissions and internally due to radon and its progeny which emit alpha particles. The study of the radiation background, which might be changing with the human activities, is necessary to establish baseline data for radioactivity background to assess pollution effects on man and environment, and to obtain a historical record of environmental quality and provide a database for future use.

Princess Nora University (PNU) is a public women's university located in the north of capital city of Riyadh in the Kingdom of Saudi Arabia (KSA). The new campus was opened officially in the north of Riyadh in 2011, with an area of about 8 million square meters. It is the world's largest and most modern women's institution of higher education in a self-contained city. Several surveillances have been carried out in KSA to measure the radioactivity in soil samples from different locations. In Riyadh city area (KSA), the activity concentrations of 238U series, 232Th series, 40K and 137Cs in soil samples were 26.0, 23.0, 315.0 and 14.0 Bq/kg dry weight respectively [1]. El-Aydarous determined the activity concentrations of 226Ra, 232Th, and 40K in soil samples from Taif city in KSA, and the mean values were 23.8, 18.6 and 162.8 Bq/kg respectively [2]. The activity concentrations of 226Ra, 232Th, and 40K in soil samples collected from various areas in Riyadh city were determined by A.Alamer, and the measured mean activity concentrations were 14.5 Bq/kg, 11.2 Bq/kg and 225 Bq/kg respectively [3].

The aim of this work is to measure the activity concentrations of 226Ra, 228Ra, 137Cs and 40K in soil, 226Ra and 228Ra in water and radon (222Rn) in some buildings to identify the background radiation and its contribution to staff, students and the public on PNU campus.

2. METHODOLOGY

Unless otherwise indicated, all references to water refer to deionized water (DDW).

2.1 Sampling

The collection of samples was performed at sixteen sampling points on the campus, as shown in map.

The soil samples were collected using a template for guidance to 25 cm2 area and a depth of 10 cm, packed in plastic bags and transferred to laboratory. The soil samples were oven-dried at 100ºc to a constant weight, homogenized, sieved, packed into 100 mL standard plastic containers and sealed for four weeks to allow secular equilibrium between 226Ra, 228Ra and their decay products. Five liters of tap water samples were collected from selected points that we thought they might be important, as they are used for drinking, and one sample from the final product of the campus water treatment unit. The water samples were acidified and transferred to laboratory. The radon measurements were carried out using a silicon semiconductor detector (RAD7) supplied by Durridge Co. The RAD-7 converts alpha radiation directly to an electric signal and has the possibility of determining electronically the energy of each particle, allowing the identification of the isotopes (218Po, 214Po) produced by radiation decay of the radon parent [4]. Radon measurements were limited to three locations according to students density, the type of building materials and lack of ventilation.

2.2 Materials and Apparatus

Radium extractions from water samples were carried out using a strong cation exchange resin, Purolite C-100 Na form, supplied by Veolia Water Co. (Riyadh, Saudi Arabia). Reference solution of 226Ra and 228Ra were supplied by the National Institute of Standards and Technology (NIST), (SRM 4967A, SRM 4339B). The 133Ba standard solution was supplied by North American Technical Services (NATS) (EZ-83879-767). The cation exchange resin was used in a column mode with BioRad Glass Econo columns of 0.9 cm diameter, together with polypropylene funnels and Teflon end fittings connected with plastic taps. All gamma radioactivity measurements were carried out using a Canberra HP Ge coaxial detector (Model GC4020) with relative photo-peak efficiencies of 40% for the 1332 keV line of 60Co. The germanium detectors were connected to a Digital Spectrum Analysis model DSA-1000.

2.3 Efficiency Calibration

The radium isotopes were determined in the water samples by extraction from 4 liters samples with a strong acid cation exchange resin (Purolite) and measured by gamma spectrometry, and the calculations of the specific

activity were performed using a comparison method with a standard resin prepared by adding a known amount of the radionuclides of interest to DDW at similar conditions (resin volume, flow rate, detector, counting time, measuring container) [5]. For soil samples, the germanium detector was calibrated using IAEA-RGU-1 reference material, the absolute efficiency at each specific energy transition of 226Ra was determined, an absolute efficiency curve was fitted and the fitting equation was exploited to calculate the target photopeak efficiencies. The calculations of the activity concentration of 226Ra was based on the gamma energy transitions of 295.1, 352.0, 609.3 keV and 1764.5 keV. For 228Ra, the gamma energy lines 338.4 and 911.2 keV were used. For 137Cs and 40K, the gamma energy lines 661.6 and 1460.8 keV were used.

2.4 Quality Assurance

For quality assurance and validation purpose, reference water and soil samples were determined using the same analysis and measurement protocol, and were compared against their certified values to test the closeness of the measured samples to its reference values. Also, intercomparison tests were carried out with the French Institute for radioprotection and nuclear safety (IRSN) (96 SL-300 reference sample) , and with the International Atomic Energy Agency, IAEA-CU-2010, IAEA-TEL-2011-03, IAEA-TEL-2012-03. Errors were propagated due to nuclear counting statistics, tracer and volume.

3. RESULTS AND DISCUSSION

In the following section, the results of the radioactivity levels in water and soil, the radon concentrations and the associated radiation doses will be represented.

3.1 Radium Isotopes in Water Samples

The activity concentrations of 226Ra and 228Ra are represented in fig. (3-1). As shown in figure, the average activity concentration of Ra-226 is 5.3 pCi/L, ranging from 3.5 to 9.6 pCi/L, while the average activity concentration of Ra-228 is 11.0 pCi/L, ranging from 9.4 to 13.2 pCi/L.

The 228Ra content in all tap water samples exceeds the national regulation limits of 2.7 pCi/L for 228Ra set by the Saudi Arabian Standards Organization (SASO) in drinking water. The tap water in the new PNU campus is supplied from a water treatment plant located in the university campus. Three additional water samples were collected from the final product of the treatment unit, analyzed for 228Ra and the average activity concentration was 9.7 ± 0.8. The radium removal efficiency in the water treatment unit depends on many factors, and we assume that it has to be evaluated.

3.2 Radioactivity in Soil Samples

Surface soil samples were collected from selected points on campus, and the activity concentrations of 226Ra, 228Ra, 137Cs and 40K are shown in table (3-1). As shown in table and fig.(3-2), the average activity concentrations of 226Ra, 228Ra, 137Cs and 40K were 9.3, 9.0, 0.2 and 122.5 Bq/kg respectively. These values are lower than those reported in literature for the activities of 226Ra, 228Ra, 137Cs and 40K in Riyadh, KSA [1, 3].

3.3 Radon indoors results

Radon (222Rn) was measured in three locations inside the campus using a radon detector RAD-7. As shown in fig.(3-3), the indoor radon concentrations ranged from 5.9 to 17.8 Bq/m3, with an average of 11.8 Bq/m3. The measured indoor radon concentrations are much lower than the recommended ICRP action level of 200- 600 Bq/m3 [6].

3.4 Assessment of Radiation Hazards

The assessment of the potential exposure of an individual to radioactivity present in the Princess Nora University Campus environment has been carried out utilizing different indices. The radium equivalent activity Raeq in Bq/kg was determined, assuming that 10 Bq/L of 226Ra, 7 Bq/L of 232Th and 130 Bq/L of 40K would produce the same gamma dose [7, 8]. The radium equivalent activities ranged from 19.9 to 49.0 Bq/kg, with an average of 31.7 Bq/kg. This value is much lower than the limit of 370 Bq/kg, as reported in the UNSCEAR, and is also lower than previous reported values in Riyadh city and Taif University campus [3, 11]. The absorbed dose rate in air from the outdoor exposure to gamma radiation in soil was determined at one meter above the ground in nGy/hr, utilizing the determined activity concentrations of 226Ra, 228Ra (232Th series) and 40K, multiplied by the dose conversion factors for these radionuclides [8], The absorbed dose rate ranged from 9.6 to 24.1 nGy/hr, with an average of 15.4 nGy/hr, which is far below the world average value of 57.0 nGy/hr [8, 10], and the reported values from different regions in KSA [2, 3, 12, 13]. Assuming an annual consumption of 730 L/year, according to the WHO Guidelines for Drinking Water Quality for adult, and the dose coefficients of the relevant

radionuclides 226Ra and 228Ra (2.8×10-7 and 6.9×10-7 Sv/Bq respectively) [7, 9], the annual effective dose was determined and had an average value of 0.24 mSv/year. This value is about one and a half order of magnitude higher than the WHO's recommended limit of 0.1 mSv/year [9].

4. CONCLUSIONS

Surveillance monitoring in the new campus of Princess Nora University has been carried out to ensure that the radiation doses received to the public are below the authorized limits, as well as providing a base-line data on background radiation inside the campus for future measurements. Radium isotopes (226Ra and 228Ra) were analyzed in tap water samples from different locations, and the average activity concentrations were found to be 5.3 and 11.0 pCi/L respectively, which is considered in violation of the Saudi Arabian Standards Organization authorized limit for 228Ra of 2.7 pCi/L, and the corresponding annual effective dose was 0.24 mSv/y, which exceeds the WHO's recommended limit of 0.1 mSv/y. The average measured activity concentrations of 226Ra, 228Ra (232Th series), 137Cs and 40K in soil were 9.3, 9.0, 0.2 and 122.5 Bq/kg respectively, and the corresponding radium equivalent activity had an average of 31.7 Bq/kg. The estimated absorbed dose rate from outdoor gamma radiation had an average value of 15.4 nGy/hr. The indoor radon concentrations had an average of 11.8 Bq/m3, which is much lower than the recommended ICRP action level of 200- 600 Bq/m3. On the basis of the current results, we may conclude that in the campus of Princess Nora University at Saudi Arabia, the levels of indoor radon in the investigated rooms are well within acceptable values, and the health hazards related to natural radiation in soils are expected to be negligible, and it is recommended that an evaluation of the campus's water treatment plant and adequate measures of radium in drinking water should be carried out.

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Table (3-1) : Activity concentrations of Ra-226, Ra-228, Cs-137 and K-40 in soil samples ± 1σ uncertainties

		Ra-226		Ra-228		Cs-137		K-40	
Location	Code	Bq/kg	±	Bq/kg	±	Bq/kg	±	Bq/kg	±
Faculty of Science	S1	9.4	0.3	10.5	0.7	0.15	0.01	93.2	4.6
Faculty of Arts	S2	9.8	0.5	8.9	0.4	0.24	0.01	116.5	6.0
Students Services	S3	10.7	0.7	11.6	0.7	0.43	0.03	176.9	16.6
Faculty of Design	S4	16.2	1.3	9.9	0.5	0.09	0.01	88.8	5.3
Students dormitory	S5	9.1	0.4	12.0	0.8	LLD*	0.0	115.3	6.1
College of Pharmacy	S6	12.3	0.9	13.4	0.8	0.39	0.03	227.2	11.6
Administration Building	S7	11.7	0.7	12.5	0.9	0.50	0.08	142.1	7.5
Staff dormitory B	S8	9.7	0.6	8.6	0.5	0.17	0.02	81.5	4.9
Staff dormitory A E	S9	8.0	0.4	8.2	0.4	LLD	0.0	140.6	6.4
College of Computer	S10	9.1	0.4	9.5	0.3	LLD	0.0	104.1	4.2
Hospital	S11	7.4	0.3	7.0	0.4	0.41	0.04	93.3	5.1
Staff dormitory A W	S12	6.7	0.2	5.9	0.3	LLD	0.0	62.3	3.2
School	S13	5.2	0.2	6.2	0.4	LLD	0.0	133.0	7.3
Services Building	S14	6.9	0.4	7.8	0.4	0.56	0.06	125.0	7.2
Sudents Club	S15	10.1	0.7	8.9	0.6	LLD	0.0	155.0	8.3
Hospital Parking	S16	6.9	0.5	3.7	0.3	LLD	0.0	105.5	6.3

The results of the activity concentrations of the investigated radionuclides (Ra-226, Ra-228, Cs-137 and K-40) in the collected soil samples.

* LLD : within the low limit of detection.

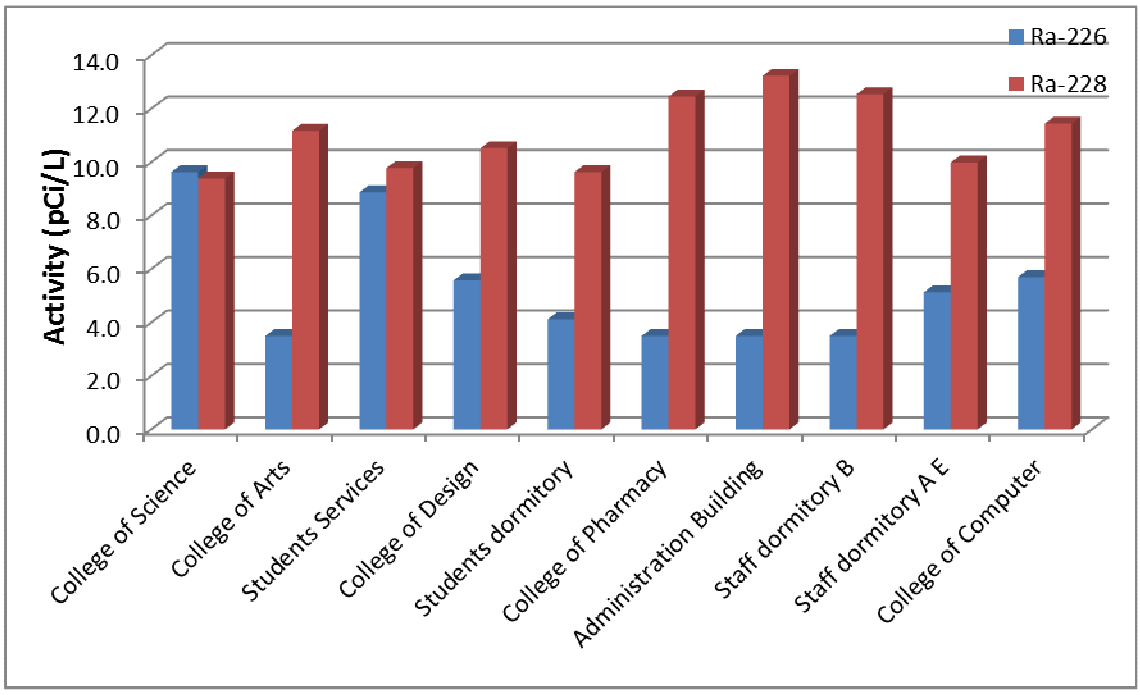

Fig. 3-1 : The activity concentrations of ^{226}Ra and ^{228}Ra in tap water samples.

This figure presents the variation of the radium isotopes (^{226}Ra and ^{228}Ra) activities in pCil/L in the drinking tap water samples.

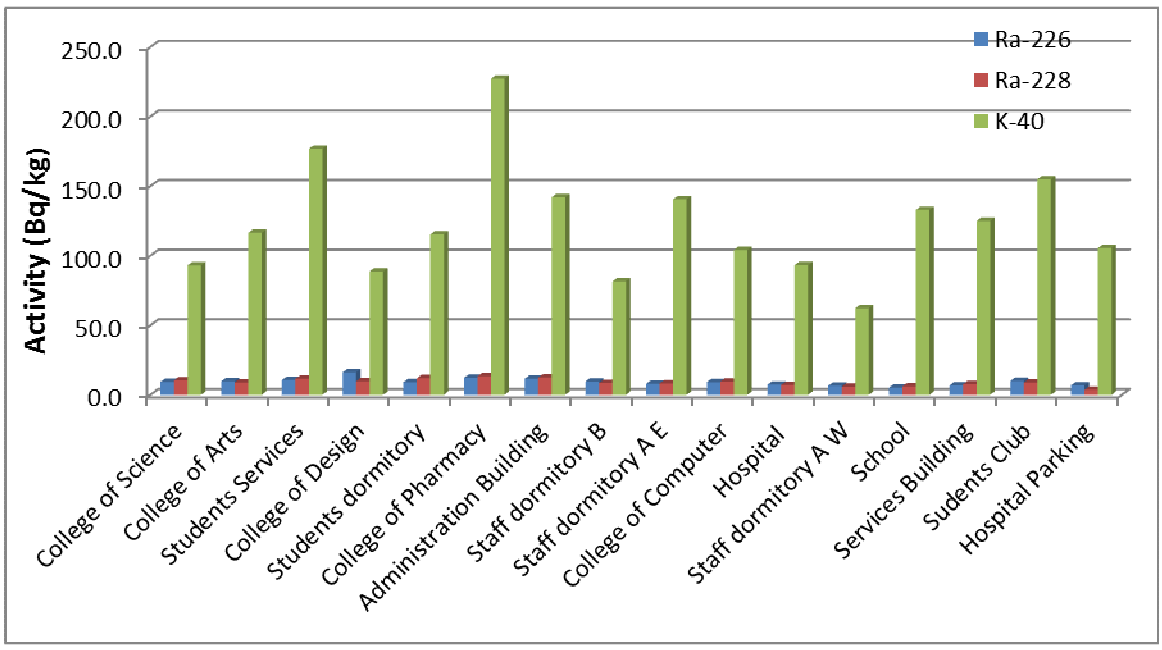

Fig. 3-2 : The activity concentrations of ^{226}Ra, ^{228}Ra, and ^{40}K in soil samples.

This figure presents the variation of the natural radionuclides (^{226}Ra, ^{228}Ra, and ^{40}K) activities in Bq/kg dry weight in the soil samples.

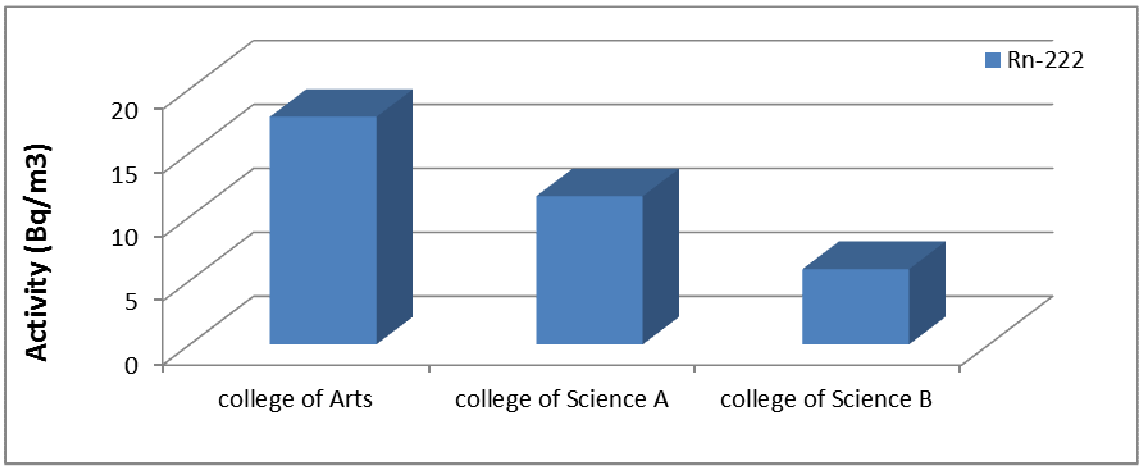

Fig. 3-3 : The concentrations of 222Rn in selected buildings.

This figure shows the activity concentration of ^{222}Rn in Bq/m^3 in the selected buildings.

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